Ontario Geological Survey
Aggregate Resources Inventory
Paper 59

Aggregate Resources Inventory of the City of Nanticoke Regional Municipality of Haldimand-Norfolk Southern Ontario

By Staff of the Engineering and
Terrain Geology Section
Ontario Geological Survey

1984

Ontario

Ministry of
Natural
Resources

Hon. Alan W. Pope
Minister

John R. Sloan
Deputy Minister

©OMNR-OGS 1984

Publications of the Ontario Ministry of Natural Resources
and price list
are obtainable through the
Ontario Ministry of Natural Resources, Map Unit, Public Service Centre
Queen's Park, Toronto, Ontario
and
The Ontario Government Bookstore
880 Bay Street, Toronto, Ontario

Orders for publications should be accompanied by cheque
or money order, payable to the Treasurer of Ontario

ISSN 0708-2061
ISBN 0-7743-6006-2

This report was prepared by: Staff of the Aggregate Assessment Office, Engineering and Terrain Geology Section of the Ontario Geological Survey, Ontario Ministry of Natural Resources, 77 Grenville Street, Toronto, M5S 1B3, Telephone (416) 965-1182.

Project Supervisor: Dale W. Scott
Text Prepared by: R. Laidlaw
Compilation and Drafting by: Staff of the Aggregate Assessment Office

The Mineral Resources Staff of Simcoe District and Southwestern Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

Parts of this publication may be quoted if credit is given to the Ontario Ministry of Natural Resources, Ontario Geological Survey. It is recommended that reference to this report be made in the following form:

Ontario Geological Survey
1984: Aggregate Resources Inventory of the City of Nanticoke, Regional Muncipality of Haldimand-Norfolk; Ontario Geological Survey, Aggregate Resources Inventory Paper 59, 35 p., 7 tables, 3 maps, scale 1:50 000.

Every possible effort is made to ensure the accuracy of the information contained in this report, but the Ministry of Natural Resources does not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

500-84-Spalding

CONTENTS

Page

Abstract v
Introduction 1
Part I - Inventory Methods 2
Field and Office Methods 2
Resource Tonnage Calculation Techniques 2
Sand and Gravel Resources 2
Bedrock Resources 3
Units and Definitions 3
Part II - Data Presentation and Interpretation 4
Map 1 Distribution of Sand and Gravel Deposits 4
Deposit Symbol 4
Texture Symbol 4
Map 2 Selected Sand and Gravel Resource Areas 5
Site Specific Criteria 5
Deposit Size 5
Aggregate Quality 5
Location and Setting 6
Regional Considerations 7
Map 3 Bedrock Resources 7
Selection Criteria 7
Selected Resource Areas 8
Part III - Assessment of Aggregate Resources in the City of Nanticoke 9
Location and Population 9
Physiography and Surficial Geology 9
Extractive Activity 10
Selected Sand and Gravel Resource Areas 10
Selected Sand and Gravel Resource Area 1 11
Selected Sand and Gravel Resource Area 2 11
Selected Sand and Gravel Resource Area 3 11
Sand and Gravel Resource Areas of Secondary Significance 12
Bedrock Geology 12
Selected Bedrock Resource Areas 12
Selected Bedrock Resource Areas 1a and 1b 13
Selected Bedrock Resource Areas 2a and 2b 13
Selected Bedrock Resource Area 3 13
Summary 14
References 25
Appendix A - Suggested Additional Reading 26
Appendix B - Glossary 27
Appendix C - Geology of Sand and Gravel Deposits 30
Appendix D - Geology of Bedrock Deposits 32

TABLES

1 - Total Sand and Gravel Resources, City of Nanticoke 15
2 - Sand and Gravel Pits, City of Nanticoke 16
3 - Selected Sand and Gravel Resource Areas, City of Nanticoke 18
4 - Total Identified Bedrock Resources, City of Nanticoke 19
5 - Quarries, City of Nanticoke 20
6 - Selected Bedrock Resource Areas, City of Nanticoke 21
7 - Summary of Test Hole Data, City of Nanticoke 22

FIGURES

1 - Key Map Showing Location of the City of Nanticoke v
2 - Bedrock Geology of Southern Ontario 32

MAPS
(back pocket)

1 - Distribution of Sand and Gravel Deposits, City of Nanticoke, Scale 1:50 000.
2 - Selected Sand and Gravel Resource Areas, City of Nanticoke, Scale 1:50 000.
3 - Bedrock Resources, City of Nanticoke, Scale 1:50 000.

ABSTRACT

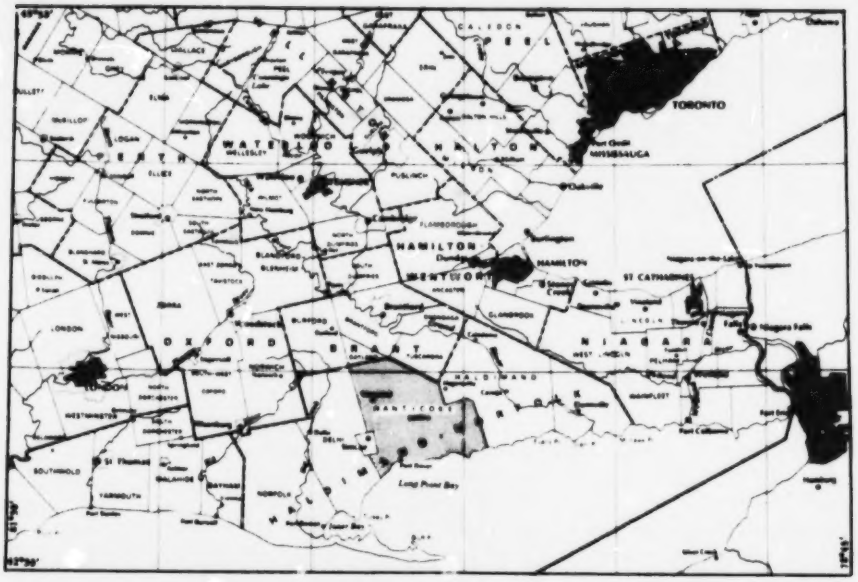


Figure 1 - Key Map Showing the Location of the City of Nanticoke, Scale 1:1 800 000.

This report includes both an inventory and evaluation of the sand and gravel and bedrock resources in the City of Nanticoke. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under The Pits and Quarries Control Act, 1971.

The City of Nanticoke contains large areas of sandy material. Coarse aggregate reserves are small and tend to be variable in quality. Three areas with the greatest resource potential have been selected for possible protection and/or development at the primary level. The Selected Sand and Gravel Resource Areas occupy 740 acres (300 ha), exclusive of licenced properties. An estimated 380 acres (154 ha) are currently available for extraction, containing 17 million tons (15 million tonnes) of possible resources.

In addition, several deposits, including buried deltaic material near Simcoe, have been selected at the secondary level. These deposits, although of more limited quality, should be considered as part of the city's aggregate supply.

The surficial deposits are underlain by limestone and dolostone of the Salina, Bertie, Bois Blanc, Onondaga and Dundee Formations. The bedrock quarry potential of the Bertie, Bois Blanc and Dundee Formations is considerable and several areas have been selected for possible protection and/or development. The Selected Bedrock Resource Areas occupy 16,500 acres (6700 ha), exclusive of licenced properties. An estimated 11,900 acres (4800 ha) are currently available, containing 1960 million tons (1780 million tonnes) of crushed stone resources.

A high chert concentration is common to most of the resource areas in the City of Nanticoke. This important quality limitation occurs in both sand and gravel and bedrock deposits. Beneficiation measures are often required to upgrade the aggregate for higher quality uses.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF THE CITY OF NANTICOKE[1]

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1979, the total tonnage of mineral aggregates extracted was 144 million tons (131 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1980).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

[1] Manuscript accepted for publication by Chief, Engineering and Terrain Geology Section, June 24, 1983.

This paper is published with the permission of V.G. Milne, Director, Ontario Geological Survey.

PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Airphotos at various scales were used to determine the continuity of deposits, especially in areas of limited subsurface information.

Deposits with potential for further extractive development or those where existing data are scarce, were studied in greater detail. Representative layers in these deposits were sampled in 25- to 100-pound (11 to 45 kg) units either from existing pit faces or from test pits dug by backhoe. The samples were analysed for grain size distribution and in some cases for petrographic assemblage. Analyses were performed by the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications. In areas of limited subsurface exposure, drilling using a powered hollow stem auger was undertaken. The stratigraphic sections in these test holes are described in drill logs included in the report as Table 7. In some cases samples taken during the course of the drilling were analysed to determine grain size distribution. The symbols for and locations of test hole sites are noted on Map 1.

In the office, the pit and field sample data were supplemented by information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Soil reports published by the Ontario Ministry of Agriculture and Food were also consulted in order to supply additional information in areas with limited data. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data

such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 represent only those parts of the deposit lying outside licenced areas (Column 2). Two successive subtractions are made from the unlicenced area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas lying outside of licenced properties that have previously been extracted (e.g. wayside pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favorable bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of a workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot (0.3 m) thick section of dolostone, one acre (0.4 ha) in extent, assuming a bulk density of 165 pounds per cubic foot (2649 kg per cubic metre)).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) or approximately 3200 tons per acre (7173 tonnes per hectare). Shale resources are calculated on the basis of a bulk density estimate of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregates are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p. 7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

PART II - DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

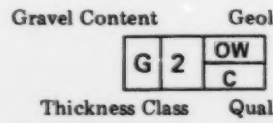
Map 1 is derived directly from the existing surficial geology maps of the area or from airphoto and field interpretation where surficial mapping is incomplete. It shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

The present level of extractive activity in the study area is indicated as follows. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are also identified and numbered on Map 1 and described in Table 2.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for a given deposit. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identify the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identify the main quality limitations that may be present in the deposit, as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken for analysis during field study. The data from which these symbols are derived has been plotted on grain size distribution graphs. The relative amounts of gravel, sand, silt, and clay in the sampled material are shown graphically by the sub-

division of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

Test hole locations are shown on Map 1 by a solid drill hole symbol.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. These areas are identified on Map 2 by different shading patterns. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by a dark shading on Map 2.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by a light shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the aggregate supply of the municipality.

Areas of tertiary significance are indicated on the map by a dashed line but have no shading. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The gravel content (G or S) indi-

cates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (or high silt and clay content) may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphaltic aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses such as concrete or structures. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

Analyses of unprocessed samples obtained from test holes and pits have been plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products — Granular Base Course A,B, and C; and Hot-Laid Asphaltic Sand Nos. 1, 2, 3, 4, 5, 6 and 8. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of those natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, power lines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report but

readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain at roughly the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, bedrock topography, drift thickness maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources), and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three shades. The darkest shade indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and licenced acreage of the quarry and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and

Communications. The main characteristics and uses of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such a resource area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN THE CITY OF NANTICOKE

LOCATION AND POPULATION

The City of Nanticoke occupies an area of 161,399 acres (65 318 ha) in the Regional Municipality of Haldimand-Norfolk, southern Ontario. The city is bounded by the Township of Delhi on the west, the Town of Haldimand on the east, and Oakland and Tuscarora Townships of Brant County on the north. The city is shown on portions of the Simcoe (40 I/16), Dunnville (30 L/13), Brantford (40 P/1) and Long Point (40 I/9) map sheets of the National Topographic System at a scale of 1:50 000.

The population of the City of Nanticoke was 19,583 in 1982 (Ontario Ministry of Municipal Affairs and Housing 1983). The city is predominantly rural in character, although several towns and villages serve as rural-residential and commercial centres. These centres include Port Dover, Waterford, Hagersville, Jarvis, Port Ryerse, Selkirk and Nanticoke. The Town of Simcoe, located just outside the city's western boundary, also serves as a regional trade centre.

The establishment of the City of Nanticoke and the regionalization of the counties of Haldimand and Norfolk have brought about changes to this rural area. The Nanticoke Industrial Complex surrounds the village of Nanticoke and includes the Stelco steel mill, an Ontario Hydro power generating station and the Texaco Canada Inc. oil and gas refinery. The Lake Erie Industrial Park to the north of Stelco and the Townsend Community Centre near Jarvis are other projects being developed within the city. Further expansion and growth may increase the demand for aggregate, while at the same time restrict access to the resources.

Road access to the aggregate resource areas includes the King's Highways 3, 6 and 24 and a network of paved and gravel-surfaced roads. The City of Nanticoke is also served by lines of the Canadian National Railways and Conrail.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The City of Nanticoke falls within three physiographic regions. A large portion of the land area consists of deltaic sands and lacustrine clays of the Norfolk Sand Plain and the Haldimand Clay Plain (Chapman and Putnam 1966, pp. 251-260). The surface is subdued, broken only by a number of streams such as Sandusk Creek, Nanticoke Creek, Black Creek and the Lynn River which flow into Lake Erie. The western boundary of the city is included in the physiographic region known as the Horseshoe Moraines (Chapman and Putnam 1966, pp. 198-203). Here, the relatively level surface of the plains is broken by the smooth slopes of the Galt Moraine - a sandy till ridge which trends north-south through Simcoe and Waterford.

The physiography and distribution of surficial materials are a result of glacial events which occurred during the late stages of the Pleistocene Epoch, informally known as the "Great Ice Age". The sand and gravel deposits shown on Map 1 are associated with the advances over a period ranging from 23 000 to 10 000 years ago, and the subsequent melting back of a massive, continental ice sheet and the submergence of the area by the development of glacial lakes approximately 10 000 years ago. The geological history of these deposits is simplified in the following paragraphs based largely upon the report by P.J. Barnett (1978).

Approximately 13 000 years ago, the ice lobe re-advanced from the northeast covering the area as far westward as the Paris Moraine in the Township of Delhi. This ice advance was also responsible for the formation of the Galt Moraine in the City of Nanticoke. The major constituent material of the Galt Moraine is Wentworth Till - a sandy silt to silt till which is exposed at the surface in the moraine north of Waterford (Barnett 1978). The till is generally too fine grained for use in aggregate products. However, the moraine also contains small deposits of ice-contact stratified drift and some overridden outwash gravels which may provide limited quantities of aggregate material.

The melting back of the Wentworth ice front was followed by submergence of the area under a low level glacial lake. Outwash sediments were deposited in a meltwater channel which flowed along the west side of the Galt Moraine. These outwash sands and gravels are exposed on the surface at Waterford Pond. The channel eventually issued into the lake near Simcoe where a large sandy delta was formed. Both the deltaic

material at Simcoe and the outwash at Waterford are important sources of aggregate in the city and have been extracted at several sites.

However, a readvance of the ice lobe raised the water levels in the glacial lake. Much of the report area, including the delta and outwash deposits, was submerged and subsequently became buried by thick layers of fine- to medium-grained lacustrine sediments which have little value as aggregate and also restrict the extraction of more valuable material. Wave action along the shores of this ancestral lake created several small beach deposits on the slopes of the Galt Moraine. Although small in extent, these deposits contain sand and gravel which has been extracted at several sites. Chert, derived from the underlying bedrock, is generally more abundant in the beach gravels than in the outwash gravels, and is an important quality limitation.

As the lake levels gradually lowered, the shallow water and deltaic deposits were exposed and slightly modified by wind action. In general, postglacial influences have been of minor importance.

EXTRACTIVE ACTIVITY

A total of twenty-one sand and gravel pits were examined in the City of Nanticoke, including several that are partly overgrown and currently inactive. At present, nine of the pits are licenced to operate under The Pits and Quarries Control Act, 1971. The licenced properties have a total area of 153.6 acres (62.2 ha) and are concentrated in the outwash deposit at Waterford Pond and the buried delta near Simcoe.

Production figures have been compiled annually by the Simcoe District Office of the Ontario Ministry of Natural Resources since designation of the area in 1976. The average annual production of sand and gravel between 1976 and 1979 was approximately 348,000 tons (315 700 tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates the deposits which contain granular material in the City of Nanticoke. The total extent of these deposits is approximately 34,000 acres (13 800 ha), representing an original tonnage of 940 million tons (850 million tonnes). However, most of the material consists of a thick layer of sandy lacustrine sediments which are unsuitable for most aggregate uses. Consequently, only a small percentage of the above acreage is suggested for possible development and/or protection.

The materials of primary value include two gravelly outwash deposits associated with the Galt Moraine meltwater channel and one beach deposit north of Waterford. These three sources have a combined area of 740 acres (300 ha), exclusive of the licenced properties. Three hundred and eighty acres (154 ha) are currently available for extraction. Total aggregate resources are, therefore, estimated to be 17 million tons (15 million tonnes) or 2 percent of the total resource tonnage.

Sources of secondary value include a number of sand and gravel outwash and beach deposits also located in the vicinity of the Galt Moraine and the buried deltaic material near Simcoe. These sources are of lower quality, but should still be considered as part of the city's aggregate supply.

The limited quantity of granular resources in the City of Nanticoke is further affected by several important quality constraints. Deike (1981, p. 12) has summarized the most important quality factors and pit workability conditions which he found to be common in the municipality. Briefly, these are:

1. Low percentages of crushable-sized gravel (greater than 1 inch or 25.4 mm) make it difficult to meet the specifications for Granular Base Course (G.B.C.) A and hot-mix coarse aggregate.

2. Chert concentrations may vary from 4 to 20 percent making beneficiation procedures necessary to produce higher-quality coarse aggregate such as Hot-Laid 4 asphalt pouring mixes.

3. The presence of excess fines in the sandy portions of pits in the area makes the material unsuitable for hot-mix or concrete fine aggregate.

4. In the more sandy deposits, the coarse sand gradation requires that the material be blended with finer sand in order to meet

hot-mix sand specifications.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is the gravel outwash deposit exposed at the surface between Waterford and the western boundary of the city. The deposit is associated with the Galt Moraine meltwater channel and water well records indicate that the outwash may continue north and south of its present boundaries in scattered locations beneath the mantle of lacustrine sand. However, it is difficult to determine the actual extent of the deposit without further subsurface data.

Resource Area 1 is a major source of aggregate material in the city and at present there are six licenced pits operating in this deposit (pit nos. 1-6). All of the pits contain water and the coarse material is extracted using a dragline. The face heights above the water table range from 8 to 25 feet (2 to 8 m) exposing gravel interbedded with sand. The overall gravel percentage averages 40 percent but some sections are predominantly sandy. Chert is present in most of the pits, although its distribution is not uniform.

In general, the deposit contains enough coarse aggregate to permit economic utilization. However, the occurrence of sandy sections and the presence of chert are important quality limitations. Granular Base Course A may be produced, although sand scalping may be required to meet gradation specifications. Selective crushing and other beneficiation measures may also be necessary to produce hot-mix asphalt (Deike 1981).

Resource Area 1 occupies 400 acres (162 ha), exclusive of the licenced properties. Deletions for the water bodies, cultural setbacks and previous extraction reduce the area available to 160 acres (65 ha). The deposit thickness ranges from 8 to 25 feet (2 to 8 m) and up to 40 feet (12 m) has been reported (Hewitt and Karrow 1963, p. 14). Assuming an average thickness of 20 feet (6 m), total resources are estimated to be 8 million tons (7 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 is a beach deposit located to the north of Waterford. This deposit was created by the wave action of a large glacial lake which reworked the morainic sediments along the east side of the Galt Moraine to produce the elongated series of beaches.

Two abandoned and overgrown pits (pit nos. 13 and 14) are located in the north end of the Resource Area. Face heights range from 10 to 12 feet (3 to 4 m) and, in places, are as high as 20 feet (6 m). The materials are predominantly sandy with interbedded gravelly layers. The overall gravel content is approximately 30 percent. Deike (1981) describes test hole logs as having sand bedding with gravel occurring at depths of 5 to 6 feet (1.5 to 2 m) below the surface. He describes coarse to medium gravel seams that range between 5.5 and 6 feet (1.7 to 2 m) thick; thinner gravel seams are separated by beds of fine to coarse sand (Deike 1981, p. 14). These characteristics are also common to pits in Resource Area 1.

Chert concentrations in the beach gravels are generally high and beneficiation measures may be necessary to improve the aggregate for use in concrete and hot-mix paving purposes. Limited quantities of crushable gravel are available for products such as G.B.C. A, B, and C, and select subgrade material.

Resource Area 2 is approximately 300 acres (121 ha). The area currently available is 210 acres (85 ha). Assuming an average deposit thickness of 15 feet (5 m), total resources are 8 million tons (7 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Sand and Gravel Resource Area 3 is the southern extension of a primary resource area in Oakland Township to the north (Ontario Geological Survey 1980). The deposit consists of glaciolacustrine sand underlain by patchy deltaic or outwash gravels (Cowan 1972).

There is no pit or subsurface information for this area. Data from the Oakland portion show that face heights range from 15 to 25 feet (5 to 8 m) and expose poorly to moderately stratified sand and gravel with an overall gravel content of 45 percent. However, Deike (1981) comments that the Nanticoke portion has low aggregate potential because of a lack of crushable-sized gravel.

Resource Area 3 has an estimated 10 acres (4 ha) currently available for extraction. Assuming an average deposit thickness of 20 feet (6 m), total resources are less than 1 million tons (less than 1 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

The largest resource area selected at the secondary level is the buried deltaic material at Simcoe. The material is primarily sandy with interbedded gravels. The deposit is overlain by up to 20 feet (6 m) of glaciolacustrine sands and clays which are unsuitable for aggregate use because of the presence of excess fines.

There are two licenced pits (pit nos. 8 and 9) and two unlicenced pits (pit nos. 18 and 19) in this area. Face heights range from 10 to 30 feet (3 to 9 m) and expose fine to medium sand and fine gravels. The lack of coarse gravels and the thickness of overlying fine sands tend to reduce the desirability of extraction. Other quality constraints include a high chert concentration and some cementation of material. In general, the aggregate is acceptable for Granular Base Course B and C and select subgrade material. Hot-laid asphalt products may be manufactured with proper blending (Deike 1981).

The remaining secondary areas include several outwash deposits, one beach deposit and one area of ice-contact stratified drift. These deposits are small in extent and contain mainly sand. Chert concentrations are also high and beneficiation measures would be necessary to improve the aggregate to acceptable levels.

BEDROCK GEOLOGY

The Paleozoic bedrock geology of the Nanticoke area, shown on Map 3, has been derived from maps by Hewitt (1972), Telford (1979), Telford and Hamblin (1980), and Telford and Tarrant (1975). Their work indicates that the city is underlain by Upper Silurian to Middle Devonian rock of the Salina, Bertie, Bois Blanc, Onondaga and Dundee Formations. These formations form a bedrock surface which slopes gently to the south-southwest and has local relief of about 30 feet (9 m). There are no major preglacial topographic features, although several minor valleys could exist and karst features have been noted near Port Dover (Barnett 1978).

Drift thickness in the eastern half of the city seldom exceeds 25 feet (8 m) and bedrock exposures are common along streams and the Lake Erie shore. The thickness of overburden increases to over 100 feet (30 m) towards the west and southwest (Barnett 1978). Since there are no bedrock exposures in this part of the map area, the interpretation of the geological boundaries is tentative (Telford and Hamblin 1980).

SELECTED BEDROCK RESOURCE AREAS

The bedrock quarry potential in the City of Nanticoke is of considerable importance. This potential is, of course, greatest in the eastern half where the depth of the overburden (i.e. lacustrine clays) ranges from less than 3 to 50 feet (1 to 15 m) thick. Seven quarries were examined in this part of the city and three of these - totalling 351.5 acres (142.2 ha) - are licenced for extraction under The Pits and Quarries Control Act, 1971. The total average annual production of crushed stone between 1976 and 1979 was approximately 1,115,400 tons (1 012 000 tonnes).

Several areas of the bedrock overlain by less than 25 feet (8 m) of drift have been selected for possible resource protection. The Selected Bedrock Resource Areas include 16,500 acres (6700 ha) of the Bertie, Bois Blanc and Dundee Formations. Approximately 11,900 acres (4800 ha) are currently available and contain 1960 million tons (1780 million tonnes) of crushed stone resources. The Salina Formation, consisting of argillaceous dolostone, shale and evaporites, is generally not acceptable for aggregate products and thus has not been selected. The Onondaga Formation generally consists of cherty, fossiliferous limestone, and has not been selected for resource protection because the rock is suited for only low-specification aggregate products.

A high chert content in the Bois Blanc and Dundee Formations is an important quality limitation. However, with selective quarrying and beneficiation techniques, crushed stone from these formations is acceptable for higher specification products such as asphalt and concrete.

It is not intended that the entire extent of the selected resource areas be reserved for resource protection. The resource selection indicates the areas where quarrying would be most easily

established. The large area available for development permits a wide range of locations to be considered, thus enabling quarry operations to be located away from areas of intense land use competition.

SELECTED BEDROCK RESOURCE AREAS 1a AND 1b

Selected Bedrock Resource Areas 1a and 1b are parts of the Bertie Formation, the oldest unit selected for possible protection. Drift thickness is less than 25 feet (8 m) and, in some areas, less than 3 feet (1 m). The unit is exposed in quarries near Springvale and just north of Hagersville outside the City of Nanticoke boundary.

Approximately 25 feet (8 m) of the formation is evident in a quarry to the north of Hagersville (Haldimand Quarries Limited). Telford and Hamblin (1980) describe the lower 10 feet (3 m) as variable, with lithologies including light grey-brown, very finely crystalline, argillaceous dolostone and grey to light grey-brown, mottled, very finely crystalline dolostone. The upper 15 feet (5 m) is described as well bedded, light brown or cream, very finely crystalline, laminated dolostone. The dolostone has been used for a variety of road-building and construction products (Hewitt 1960).

Resource Areas 1a and 1b cover 2320 acres (940 ha), of which 1720 acres (700 ha) are currently available. As the unit may vary from 33 to 66 feet (10 to 20 m) thick, an average workable thickness of 50 feet (15 m) was used for the resource tonnage calculations. Estimated quantities of crushed stone are, therefore, 310 million tons (280 million tonnes).

SELECTED BEDROCK RESOURCE AREAS 2a AND 2b

Selected Bedrock Resource Areas 2a and 2b are parts of the Bois Blanc Formation. This formation is the next oldest unit and subcrops to the north of the Onondaga Formation. The Resource Areas are covered by less than 25 feet (8 m) of drift and in some areas by less than 3 feet (1 m). The formation is exposed in the quarries near Hagersville where the unit is about 25 feet (8 m) thick.

The lower part of the Bois Blanc Formation (the Springvale Sandstone Member) consists of greenish grey, glauconitic, quartzose sandstone occasionally interbedded with chert, cherty dolomitic limestone and white to light brown, fossiliferous quartzose sandstone (Telford and Hamblin 1980). The sandstone was quarried near Springvale for building stone and used in local construction (Barnett 1978). The remainder of the formation consists of irregularly bedded, light brown or grey, very cherty, fossiliferous, bioclastic limestone. The stone is acceptable for hot-mix and concrete products with the use of beneficiation techniques (Deike 1981).

Resource Areas 2a and 2b have approximately 4100 acres (1660 ha) currently available for extraction. Based on subsurface information, the Bois Blanc Formation in this area is only 25 to 30 feet (8 to 9 m) thick. Since the underlying Bertie Formation is also suitable for extraction, the workable thickness for the Resource Area is extended to 60 feet (18 m) and includes both formations. Total crushed stone resources are, thus, estimated to be 880 million tons (800 million tonnes).

SELECTED BEDROCK RESOURCE AREA 3

Selected Bedrock Resource Area 3 consists of part of the Dundee Formation overlain by less than 25 feet (8 m) of drift in the southeast corner of the city. The Dundee Formation is the youngest bedrock unit to subcrop in the city and is described by Hewitt (1972) as a light brown, medium-grained limestone. Chert is often present and occurs as small nodules or in thin irregular beds (Telford and Hamblin 1980).

Although there are no quarries operating in the Resource Areas, the Dundee Formation is being worked northeast of Port Dover in less than 50 feet (15 m) of overburden. Thirty-five- to 50-foot (11 to 15 m) faces were observed in this quarry (Q3) which has 129.0 acres (52.2 ha) licenced for extraction. Stone from the quarry is taken from the upper Dundee Formation limestone which is of poor quality in some areas because of the presence of white, porous chert. However, the limestone is acceptable for hot-mix and concrete uses if chert-prone areas are avoided (Deike 1981). The lower levels of the formation contain stone of more acceptable quality.

Resource Area 3 totals 9100 acres (3700 ha), of which 6100 acres (2470 ha) are currently available. Telford and Hamblin (1980) have reported that quarry no. 3 contained the maxi-

mum exposed thickness of the Dundee Formation in the Simcoe map-area, although oil and gas wells further to the southwest have encountered thicknesses up to about 70 feet (21 m). Since the Dundee Formation becomes thinner in the eastern part of the report area, a workable thickness of 35 feet (11 m) is assumed. Possible crushed stone resources are approximately 770 million tons (700 million tonnes).

SUMMARY

The sand and gravel deposits of the City of Nanticoke are the product of glacial activity which occurred during the "Great Ice Age". Glaciolacustrine sand covers most of the land surface inhibiting extraction and incorporating excess fine-grained material in many aggregate sources. Crushable gravel is available in limited quantities, although high chert concentrations tend to reduce its quality. Three areas with the greatest resource potential were selected at the primary level for possible protection. These include two outwash deposits north of Waterford and one beach deposit along the slopes of the Galt Moraine. Total available aggregate resources are estimated to be 17 million tons (15 million tonnes). Additional resources may be available in the buried delta at Simcoe as well as in several smaller deposits selected at the secondary level. In general, the aggregate is acceptable for a variety of road-building and construction products provided the appropriate beneficiation techniques are employed.

The surficial deposits are underlain by limestone and dolostone of the Salina, Bertie, Bois Blanc, Onondaga and Dundee Formations. The Bertie, Bois Blanc and Dundee Formations are valuable sources of crushed stone and three areas were selected for resource protection. The selected areas are covered by less than 25 feet (8 m) of overburden, making extraction economically feasible. Total possible resources are estimated to be 1960 million tons (1780 million tonnes). Chert is a limiting factor, but its effect can be reduced by beneficiation methods.

Enquiries regarding the Aggregate Resources Inventory of the City of Nanticoke should be directed to the Ontario Ministry of Natural Resources either at the Simcoe District Office, 645 Norfolk Street North, Simcoe, Ontario, N3Y 3R2 (Tel. (519) 426-7650) or at the Southwestern Region Geological Office, 458 Central Avenue, London, Ontario, N6B 2E5 (Tel. (519) 433-8431).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, CITY OF NANTICOKE

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
1	S-IC	44 (18)	2 (2)
	G-OW	940 (380)	47 (43)
	S-OW	365 (148)	18 (16)
	S-OW (Buried)	2350 (950)	118 (107)
2	S-AL	690 (280)	17 (15)
	S-IC	72 (29)	3 (3)
	G-LB	52 (21)	1 (1)
	S-LB	275 (111)	12 (11)
	S-LP	27,000 (10 900)	690 (630)
	S-OW	65 (26)	2 (2)
3	S-AL	124 (50)	2 (2)
	S-WD	300 (121)	5 (4)
4	S-LB	120 (49)	1 (1)
	S-LP	1700 (690)	17 (15)
		34,000 (13 800)	940 (850)

N.B. Minor variations in tables are caused by rounding of data.

TABLE 2 | SAND AND GRAVEL PITS, CITY OF NANTICOKE

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
1	–	Waterford Sand and Gravel	1, 2	9	52.8 (21.4)	8 (2)	–
2	–	Waterford Sand and Gravel	2	9	3.4 (1.4)	25 (8)	40
3	–	Waterford Sand and Gravel	2	9	6.0 (2.4)	25 (8)	40
4	–	City of Nanticoke	2	9	7.0 (2.8)	25 (8)	40
5	–	City of Nanticoke	2	9	2.9 (1.2)	20 (6)	40
6	–	City of Nanticoke	3	9	17.8 (7.2)	20 (6)	40
7	–	Regional Municipality of Haldimand-Norfolk	8	12	8.0 (3.2)	20 (6)	–
8	–	Cookson Construction Ltd.	4	3	46.6 (18.9)	30 (9)	20
9	–	Albert Thompson	5	2	9.1 (3.7)	25 (8)	10
					153.6 (62.2)		
UNLICENCED PITS*							
10	S6-53	Overbaugh	1	2	–	10 (3)	C sand
11	S6-68	Bot Construction	2	3	–	12 (4)	0 sand
12	S6-20	Stickler	4, 5	3	–	15 (5)	–
13	S6-23	Hardy Bros. (Twp. of Townsend)	6	4	–	10 (3)	30

TABLE 2 | SAND AND GRAVEL PITS, CITY OF NANTICOKE

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
14	S6-24	M.T.C. (Unknown)	6	5	–	12 (4)	–
15	S6-43	Waterford Sand and Gravel	2	7	–	30 (9)	60
16	S6-110	Waterford Sand and Gravel	3	9	–	10 (3)	10
17	S6-55	City of Nanticoke	1, 2	9	–	10 (3)	20
18	S6-28	Smythe	5	3	–	10 (3)	10
19	S6-13	Thompson	5	2	–	30 (9)	0 sand
20	S6-6	J. Riss	14	13	–	20 (6)	0 sand
21	S6-7	Norfolk County (Stuart)	8	12	–	15 (5)	–

* Abandoned or wayside pits operating on demand under authority of a permit.

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, CITY OF NANTICOKE

1 **DEPOSIT NO.**	2 **UNLICENCED AREA** Acres (Hectares)	3 **CULTURAL SETBACKS** Acres (Hectares)	4 **EXTRACTED AREA** Acres (Hectares)	5 **AVAILABLE AREA** Acres (Hectares)	6 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	7 **AVAILABLE AGGREGATE** Millions of Tons (Tonnes)
1	400 (162)	215 (87)	25 (10)	160 (65)	20 (6)	8 (7)
2	300 (121)	85 (34)	5 (2)	210 (85)	15 (5)	8 (7)
3	40 (16)	30 (12)	0 (0)	10 (4)	20 (6)	<1 (<1)
	740 (300)	330 (134)	30 (12)	380 (154)		17 (15)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, CITY OF NANTICOKE

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
0-3 (0-1)	Dundee	50 (15)	380 (154)	68 (62)
3-25 (1-8)	Dundee	50 (15)	14,000 (5700)	2500 (2270)
25-50 (8-15)	Dundee	50 (15)	28,000 (11 300)	5000 (4550)
0-3 (0-1)	Onondaga	60 (18)	1210 (490)	260 (236)
3-25 (1-8)	Onondaga	60 (18)	28,500 (11 500)	6200 (5600)
25-50 (8-15)	Onondaga	60 (18)	11,100 (4500)	2400 (2180)
0-3 (0-1)	Bois Blanc	30 (9)	1310 (530)	142 (129)
3-25 (1-8)	Bois Blanc	30 (9)	3800 (1540)	410 (370)
25-50 (8-15)	Bois Blanc	30 (9)	3000 (1210)	325 (295)
0-3 (0-1)	Bertie	50 (15)	175 (71)	32 (29)
3-25 (1-8)	Bertie	50 (15)	2220 (900)	400 (365)
25-50 (8-15)	Bertie	50 (15)	6500 (2650)	1170 (1060)
3-25 (1-8)	Salina	60 (18)	285 (115)	55 (50)
25-50 (8-15)	Salina	60 (18)	1020 (415)	196 (178)
			102,000 (41 500)	19,200 (17 400)

TABLE 5 | QUARRIES, CITY OF NANTICOKE

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
LICENCED QUARRIES						
1	S6-15	Standard Industries	13 14	13	138.5 (56.0)	30-40 (9-12)
2	–	Dufferin Materials & Construction Ltd.	12	12	84.0 (34.0)	25 (8)
3	S6-51	Norfolk Quarries Co.	13, 14 15	2	129.0 (52.2)	35-50 (11-15)
					351.5 (142.2)	
UNLICENCED QUARRIES*						
4	S6-91	Ontario Land Corporation	24	13		23 rehabi- (7) litated
5	S6-16	Dufferin Materials & Construction Ltd.	13	13		30 (9)
6	S6-44	Cayuga Materials & Construction Ltd. (Simcoe Quarry)	7	14		
7	–	Stelco	24	1		40-50 (12-15)

* Abandoned or wayside quarries operating on demand under authority of a permit.

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, CITY OF NANTICOKE

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
1a	0-25 (0-8)	1200 (485)	300 (121)	2 (1)	900 (365)	50 (15)	162 (147)
1b	0-25 (0-8)	1120 (455)	300 (121)	0 (0)	820 (330)	50 (15)	148 (134)
		2320 (940)	600 (243)	2 (1)	1720 (700)		310 (280)
2a	0-25 (0-8)	4200 (1700)	800 (325)	0 (0)	3400 (1380)	60* (18)	730 (660)
2b	0-25 (0-8)	900 (365)	200 (81)	0 (0)	700 (285)	60* (18)	151 (137)
		5100 (2060)	1000 (405)	0 (0)	4100 (1660)		880 (800)
3	0-25 (0-8)	9100 (3700)	3000 (1210)	0 (0)	6100 (2470)	35 (11)	770 (700)
		16,500 (6700)	4600 (1860)	2 (1)	11,900 (4800)		1960 (1780)

* Includes the Bois Blanc Formation and the underlying Bertie Formation.

TABLE 7 | SUMMARY OF TEST HOLE DATA, CITY OF NANTICOKE

Test Hole Number: NC-TH-1

Location: Lot 3, Conc. 2 (Woodhouse)

Elevation: Approx. 720 feet (220 m) a.s.l.

Date: October 16, 1980

DEPTH Feet (metres)	DESCRIPTION
5-15 (1.5-4.6)	medium to coarse sand with some granules
20 (6.1)	medium sand
25 (7.6)	slightly silty fine to medium sand
30 (9.1)	fine to coarse sand
35 (10.7)	fine to coarse sand; bottom of sample silt and clay
	hole collapsed at 40 feet (12.2 m)

Test Hole Number: NC-TH-2

Location: Lot 4, Gore Conc. (Woodhouse)

Elevation: Approx. 730 feet (222 m) a.s.l.

Date: October 16, 1980

DEPTH Feet (metres)	DESCRIPTION
5 (1.5)	oxidized medium to coarse sand
10 (3.0)	slightly silty fine to coarse sand with some granules
15-25 (4.6-7.6)	medium to coarse sand with granules; chips of larger clasts present.
30 (9.1)	fine to coarse sand with granules and some pebbles
	hole collapsed at 35 feet (10.7 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, CITY OF NANTICOKE

Test Hole Number: NC-TH-3

Location: Lot 4, Gore Conc. (Woodhouse)

Elevation: Approx. 735 feet (224 m) a.s.l.

Date: October 16, 1980

DEPTH Feet (metres)	DESCRIPTION
5 (1.5)	fine to medium sand
10-15 (3.0-4.6)	silty fine sand with some granules
20-25 (6.1-7.6)	silty fine to coarse sand with few granules
30-35 (9.1-10.7)	fine to coarse sand with some fine gravel
40 (12.2)	medium to coarse sand

Test Hole Number: NC-TH-4

Location: Lot 5, Conc. 6 (Townsend)

Elevation: Approx. 830 feet (253 m) a.s.l.

Date: October 17, 1980

DEPTH Feet (metres)	DESCRIPTION
5-10 (1.5-3.0)	medium to coarse sand with some gravel
15-20 (4.6-6.1)	buff-brown, stony silty sand till
25 (7.6)	silty fine to medium sand with some chips of gravel
30-35 (9.1-10.7)	silty massive clay with interlayered fine sand
40 (12.2)	fine to coarse sand overlying stony silty sand till

TABLE 7 | SUMMARY OF TEST HOLE DATA, CITY OF NANTICOKE

Test Hole Number: NC-TH-5

Location: Lot 5, Conc. 6 (Townsend)

Elevation: Approx. 800 feet (244 m) a.s.l.

Date: October 17, 1980

DEPTH Feet (metres)	DESCRIPTION
5-10 (1.5-3.0)	silty fine sand
15-20 (4.6-6.1)	coarse sand with fine gravel
25 (7.6)	coarse sand with some granules
30 (9.1)	fine to coarse sand overlying clayey silt

REFERENCES

Association of Professional Engineers of Ontario
1976: Performance Standards for Professional Engineers Advising on and Reporting on Oil, Gas and Mineral Properties; Association of Professional Engineers of Ontario, 11 p.

Barnett, P.J.
1978: Quaternary Geology of the Simcoe Area, Southern Ontario; Ontario Division of Mines, Geoscience Report 162, 74 p. Accompanied by Maps 2369, 2370 and 2371, scale 1:50 000.

Chapman, L.J. and Putnam, D.F.
1966: The Physiography of Southern Ontario; Second Edition, Ontario Research Foundation, University of Toronto Press, Toronto, 386 p.

Cowan, W.R.
1972: Pleistocene Geology of the Brantford Area, Southern Ontario; Ontario Department of Mines and Northern Affairs, Industrial Mineral Report 37, 66 p. Accompanied by Maps 2240 and 2241, scale 1:63 360.

Deike, W.
1981: Aggregate Suitability Evaluation, City of Nanticoke, Regional Municipality of Haldimand-Norfolk; Aggregate Sources Research, 28 p., unpublished report.

Feenstra, B.H.
1974: Quaternary Geology of the Dunnville Area, Southern Ontario; Ontario Division of Mines, Preliminary Map P. 981, Geological Series, scale 1:50 000.

Hewitt, D.F.
1960: The Limestone Industries of Ontario; Ontario Division of Mines, Industrial Mineral Circular 5, 177 p.
1972: Paleozoic Geology of Southern Ontario; Ontario Division of Mines, Geological Report 105, 18 p. Accompanied by Map 2254, scale 1:1 013 760.

Hewitt, D.F. and Karrow, P.F.
1963: Sand and Gravel in Southern Ontario; Ontario Department of Mines, Industrial Mineral Report 11, 151 p.

Ontario
1983: The Pits and Quarries Control Act, 1971; Revised Statutes of Ontario, 1980, Chapter 378, Queen's Printer for Ontario.

Ontario Geological Survey
1980: Aggregate Resources Inventory of Oakland Township, Brant County; Ontario Geological Survey, Aggregate Resources Inventory Paper 33, 30 p., 6 tables, 3 maps, scale 1:50 000.

Ontario Interministerial Committee on National Standards and Specifications (Metric Committee)
1975: Metric Practice Guide; 67 p.

Ontario Ministry of Municipal Affairs and Housing
1983: Municipal Directory 1983; Queen's Printer for Ontario, 241 p.

Ontario Ministry Of Natural Resources
1980: Statistics 1980; Ontario Ministry of Natural Resources, 122 p.

Robertson, J.A.
1975: Mineral Deposit Studies, Mineral Potential Evaluation, and Regional Planning in Ontario; Ontario Division of Mines, Miscellaneous Paper 61, 42 p.

Telford, P.G.
1979: Paleozoic Geology of the Brantford Area, Southern Ontario; Ontario Geological Survey, Preliminary Map P. 1984, Geological Series, scale 1:50 000.

Telford, P.G. and Hamblin, A.P.
1980: Paleozoic Geology of the Simcoe Area, Southern Ontario; Ontario Geological Survey, Preliminary Map P. 2234, Geological Series, scale 1:50 000.

Telford, P.G. and Tarrant, G.A.
1975: Paleozoic Geology of the Dunnville Area, Southern Ontario; Ontario Division of Mines, Preliminary Map P. 988, Geological Series, scale 1:50 000.

APPENDIX A - SUGGESTED ADDITIONAL READING

American Geological Institute
1972: Glossary of Geology; Washington, D.C., 858 p.

Bauer, A.M.
1970: A Guide to Site Development and Rehabilitation of Pits and Quarries; Ontario Department of Mines, Industrial Mineral Report 33, 62 p.

Cowan, W.R.
1977: Toward the Inventory of Ontario's Mineral Aggregates; Ontario Geological Survey, Miscellaneous Paper 73, 19 p.

Fairbridge, R.W. (ed.)
1968: The Encyclopedia of Geomorphology; Encyclopedia of Earth Sciences, Vol. III, Reinhold Book Corp., N.Y., 1295 p.

Flint, R.F.
1971: Glacial and Quaternary Geology, John Wiley and Sons Inc., 892 p.

Hewitt, D.F.
1960: The Limestone Industries of Ontario; Ontario Department of Mines, Industrial Mineral Circular 5, 177 p.
1964a: Building Stones of Ontario, Part I Introduction; Ontario Department of Mines, Industrial Mineral Report 14, 43 p.
1964b: Building Stones of Ontario, Part II Limestone; Ontario Department of Mines, Industrial Report 15, 43 p.
1964c: Building Stones of Ontario, Part III Marble; Ontario Department of Mines, Industrial Mineral Report 16, 89 p.
1964d: Building Stones of Ontario, Part IV Sandstone; Ontario Department of Mines, Industrial Mineral Report 17, 57 p.
1972: Paleozoic Geology of Southern Ontario; Ontario Division of Mines, Geological Report 105, 18 p.

Hewitt, D.F. and Karrow, P.F.
1963: Sand and Gravel in Southern Ontario; Ontario Department of Mines, Industrial Mineral Report 11, 151 p.

Hewitt, D.F. and Vos, M.A.
1970: Urbanization and Rehabilitation of Pits and Quarries; Ontario Department of Mines, Industrial Mineral Report 34, 21 p.

Lowe, S.B.
1980: Trees and Shrubs for the Improvement and Rehabilitation of Pits and Quarries in Ontario; Ontario Ministry of Natural Resources, 71 p.

McLellan, A.G.; Yundt, S.E. and Dorfman, M.L.
1979: Abandoned Pits and Quarries in Ontario; Ontario Geological Survey, Miscellaneous Paper 79, 36 p.

Ontario Mineral Aggregate Working Party
1977: A Policy for Mineral Aggregate Resource Management in Ontario; Ontario Ministry of Natural Resources, 232 p.

Ontario Ministry of Natural Resources
1975: Vegetation for the Rehabilitation of Pits and Quarries; Forest Management Branch, Division of Forests, 38 p.

Peat, Marwick & Partners and
M.M. Dillon Limited
1981: Mineral Aggregate Transportation Study; Industrial Minerals Background Paper 1, 133 p. Summary Report 26 p.

Proctor and Redfern Limited
1974: Mineral Aggregate Study, Central Ontario Planning Region; Prepared for the Ontario Ministry of Natural Resources, over 100 p.

Proctor and Redfern Limited and
Gartner Lee Associates Limited
1975: Mineral Aggregate Study of Part of The Eastern Ontario Region; Prepared for the Ontario Ministry of Natural Resources, about 200 p.
1977: Mineral Aggregate Study and Geological Inventory, Southwestern Region of Ontario; Prepared for the Ontario Ministry of Natural Resources, about 200 p.

APPENDIX B - GLOSSARY

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

ALKALI-AGGREGATE REACTION

A chemical reaction between the alkalies of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

BLENDING

Required in cases of extreme coarseness, fineness or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

CAMBRIAN

The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

CLAST

An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

CRUSHABLE AGGREGATE

Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN

A period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited

in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

GLACIAL LOBE

A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GRADATION

The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

HOT-LAID (OR ASPHALTIC) AGGREGATE

Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2, 6 and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

MELTWATER CHANNEL

A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

ORDOVICIAN

An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA

One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

PETROGRAPHIC EXAMINATION

An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

PLEISTOCENE

An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

POSSIBLE RESOURCE

Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

SILURIAN

An early period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good-quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout southern Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAINS (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

WINDBLOWN DEPOSITS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

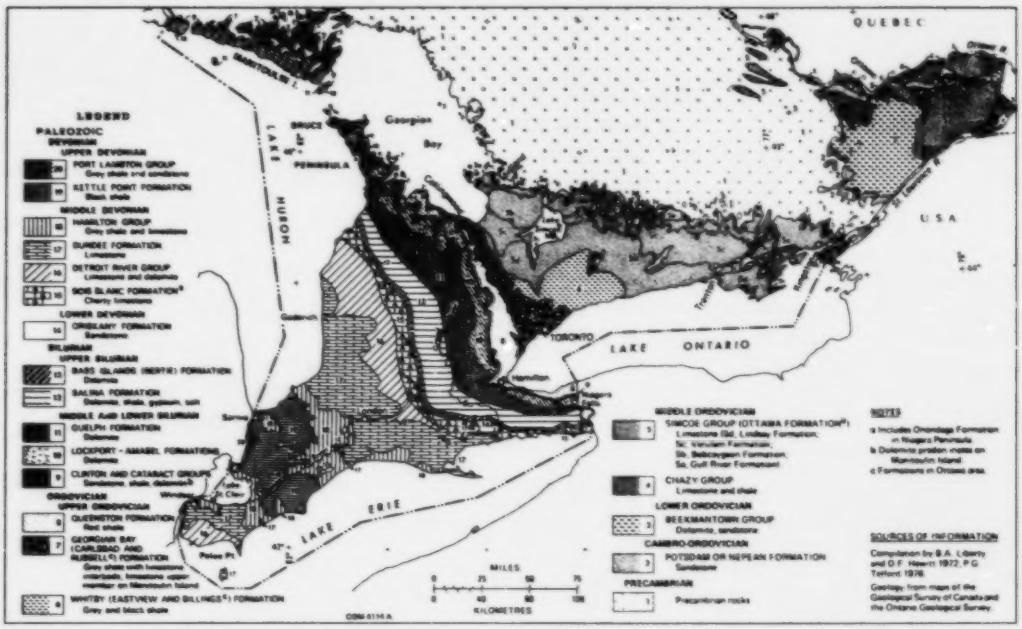


Figure 2 - Bedrock Geology of Southern Ontario

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

BASS ISLANDS FORMATION (UPPER SILURIAN)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate due to high soundness losses.

BOBCAYGEON FORMATION (MIDDLE ORDOVICIAN)

Composition: Compact, homogeneous, medium to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

BOIS BLANC FORMATION (LOWER-MIDDLE DEVONIAN)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

DUNDEE FORMATION (MIDDLE DEVONIAN)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone.

Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

GULL RIVER FORMATION (MIDDLE ORDOVICIAN)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County, and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

LOCKPORT AND AMABEL FORMATIONS (MIDDLE SILURIAN)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

ONONDAGA FORMATION (MIDDLE DEVONIAN)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey brown. fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

OTTAWA FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

OXFORD FORMATION (LOWER ORDOVICIAN)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

DETROIT RIVER GROUP (MIDDLE DEVONIAN)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces 80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for

crushed stone.

GRENVILLE MARBLE (PRECAMBRIAN)

Composition: Recrystallized white limestone and dolostone, fine- to coarse-grained, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

GUELPH FORMATION (MIDDLE SILURIAN)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

LINDSAY FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Member: fine-crystalline, rubbly, nodular-weathering limestone. Upper Member: grey calcareous claystone with shaly partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

VERULAM FORMATION (MIDDLE ORDOVICIAN)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for cement. The formation is unsuitable for crushed stone due to clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

GEORGIAN BAY FORMATION (UPPER ORDOVICIAN)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in Metro Toronto and Cooksville produce brick and structural tile. Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

HAMILTON GROUP (MIDDLE DEVONIAN)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

QUEENSTON FORMATION (UPPER ORDOVICIAN)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

NEPEAN (POTSDAM) FORMATION (CAMBRO-ORDOVICIAN)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

SALINA FORMATION (UPPER SILURIAN)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum.

The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

WHITBY FORMATION (UPPER ORDOVICIAN)

(Formerly known as Collingwood Shale near Toronto) Composition: Brown to black fissile shale. Uses: Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggregate.

MAPS NOT

FILMED

CARTES

OMISES